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ERRATA

Page 1 — In Résumé, line 5, ' importation'

In Résumé, line 13, ' atténué '

Page 3 — 2nd column, paragraph 4, line 3, ' pharyngeal '

paragraph 4, line 6, ' striking '

Page 5 — 2nd column, paragraph 1, line 4, ' some '

paragraph 4, line 3, to delete ' some '

Page 6 — 2nd column, paragraph 4, line 1, ' The bee louse '

Page 7 — 1st column, paragraph 2, line 7, ' dies '

Page 11 — 2nd column, paragraph 1, line 5, ' generally '

2nd column, paragraph 2, line 3, ' quantify '

2nd column, paragraph 3, line 6, ' Latosolic '

Page 14 — 2nd column, paragraph 2, line 1, ' influence '

Page 19 — Under conclusions, 3, ' quality '

Page 19 — Under References, ' Deane ' instead of ' Dean '

Page 20 — In Résumé, line 1, ' variétés x dates '

Page 20 — Column 2, line 7 delete ' bean ', last line of five bean cultivars

Page 21 — 2nd column, line 2, ' Y ' instead of ' y '

Page 23 — Table II, ' Planting date 17.6.81 instead of 17.6.84

Page 24 — Tables III & IV, under varieties ' Noorimbee '

Page 26 — Table I, ' Different '

Page 30 — Last line ' $h = \frac{4\,Dv}{\pi d^2}$

Facets of Bee-farming and Pests of Bees in Mauritius

by
MOORGESSEN PILLAY RAMSAMY
Scienfific Officer (Entomology)

Résumé

L'apiculture est une activité relativement facile, agréable et profitable. Adoptée à l'échelle de petites industries, elle aidera dans une certaine mesure à réduire les pertes en devises étrangères découlant de l'imporatation de miel et de cire.

L'apiculture nécessite un investissement minimal et peu de main d'oeuvre.

L'île Maurice, se situant dans une zone cyclonique ne pourrait aspirer a être exportatrice de miel. Cependant si les apiculteurs sont disposés à prendre quelques précautions élémentaires. l'effet des cyclones sur les populations abeillères pourrait être considérablement attenués et la production de miel maintenue à un niveau raisonnable.

Les ennemis des abeilles sont peu nombreux et, à l'exception des phalènes de la cire, sont tous facilement contrôlables. Les maladies majeures des pays producteurs de miel n'étant pas présentes dans l'île, il n'y a aucune raison pour que l'apiculture ne devienne une occupation populaire

Summary

Bee-farming is to day a relatively easy, enjoyable and profitable activity, which, if adopted as a cottage industry will help to curb losses in foreign exchange resulting from import of honey and wax. Beekeeping involves little capital investment and almost no labour.

Mauritius may not become a honey exporting country because it is situated in a cyclonic belt, but, if bee-farmers are willing to take some slight precautions, the effect of cyclones on the bee population may be mitigated and honey production kept at a reasonable level.

The pests of bees are few, and, with the exception of the wax moths, are all easily manageable. The country is free from major diseases common to honey producing countries and no reason is seen why honey production should not become a popular occupation.

PART I

Introduction

The exact date bees were first introduced in Mauritius is an enigma. Smith (1960) stated that the black bee race *Apis mellifera unicolor* Latreille is confined to Madagascar, Réunion and Mauritius, but, he did not mention whether the black bee was endemic to all these areas. Crane (1975) produced a world bee distribution map with 17 races of bees and pointed that *Apis mellifera unicolor* is endemic to Madagascar. According to Bappoo (1981), de Sornay in 1950 mentioned that the black bee was introduced by the French in Réunion and Mauritius in the 17th Century. This is perhaps true for Réunion but, for Mauritius, it is extremely unlikely, because from 1598 up to 1710, this country was under Dutch occupation (Mourba 1981). It is more probable that the black bee was introduced in Mauritius either by the Dutch during their occupation or by the French, later in the 18th century.

Mr. Claude Rouillard, a pioneer beekeeper of Mauritius, personally brought a ship consignment of the Italian race, *Apis mellifera lingustica* from France in 1930 (Christian 1980). From 1970 up to the present, a large number of queens of the Italian race and its hybirds have been imported in several small air consignments. As a consequence of such importations, the black bee of Mauritius has become considerably hybridized and to-day, it is hard to come across a wild black bee colony without finding some of its members with traits of the Italian race.

Bee keeping and honey production began a more favourable turn as from 1969, when the foremost beekeepers of the Island grouped into the first apicultural organisation called La Societé Apicole de l'Ile Maurice. Sixteen years later, in 1975, the Mauribee Producer Society took birth with 15 members

only. To-day, its membership is extended to over 100 and it is still growing steadily. A third bee farming organisation, Maurimiel and Co., a society whose membership is limited to 20, became established in 1980.

The efforts of these apicultural societies and individual bee farmers have culminated in increased honey productoin. However, demographic expansion, increase in *income per capita* with the concomitant improvement in standard of living, and popularization of honey as a valuable and versatile foodstuff are some of the factors preventing local production from keeping up to demand—annual importations have inevitably also increased. In order to curtail loss in foreign exchange and to boost up local honey production to the level of at least self sufficiency, revival of public interest in apiculture has become an important policy of the Extension Service Division of the Ministry of Agriculture, Fisheries and Natural Resources.

This paper presents a brief description of some simple but interesting facets of bee farming with the aim of clarifying a number of points still puzzling prospective bee farmers and the profane in apiculture. Some of the information presented have been abstracted from well known books on apiculture such as: *(a)* ABC to XYZ of bee culture (Roots, 1959); *(b)* Honey, a comprehensive survey (Crane, 1976) and *(c)* Beekeeping in the Tropics (Smith, 1960). The paper also enumerates and discusses some of the major problems (and pests) Mauritian bee farmers are likely to encounter and it proposes some pratical solutions on how to deal with them.

The Place of Bees in the Animal World

Bees belong to the great class of animals known as insects and like the majority of insects they have two pairs of wings, 3 pairs of legs and a pair of antennae. The body of the adult bee, similar to that of most insect, is divided into 3 parts namely: the head, with a central nervous system and associated main and sensorial organs such as the eyes and antennae: the thorax with the locomotory organs namely the legs and wings; and the abdomen, which contains the gut and other internal structures.

Bees belong to the order Hymenoptera which includes such familiar insects as the wasps and ants. Within this group of insect high degrees of social organisation, morphological complexity and behavioural adaptation have envolved and it is only in the Isoptera, another order of social insects, the termites,that such a parallel is met.

Races of Bees

Most of the world's honey is produced by *Apis mellifera*, the commonest races of which are:—

A. m. lingustica, Italian;

A. m. caucasia, European;

A. m. carnica, Carniolan;

A. m. adansonii, African;

A. m. unicolor, Malagassian.

All of them are stinging bees. Other species of stinging bees which store honey are: *Apis florea, Apis cerana* and *Apis dorsata*. Stingless honey bees are also found in the hymenopterous family Melliponinae. *Melipona* and *Trigona* are examples of genera of stingless bees existing on the American, African, Asian and Australian continents. Bumble bees *(Bombus)* also store honey but they are not socially well organised as honey bees and the amount of honey they store is not important.

Our local black bee, *Apis mellifera unicolor* which originated from Madagascar has become hybridized with the Italian race (and its hybrid) imported from U.S.A. and Europe. The local hybrids, in general, are good foragers but some are highly temperamental and will readily attack anyone approaching the hive, especially in periods of honey flow.

All the above mentioned pure races of *Apis mellifera* are satisfactory honey producers. However, bee breeders have produced special hybrids of the Italian and Caucasian races such as the Starline, Midnite and Buckfast, which have been tailored with traits of particular apicultural interests. viz: good foraging ability, high prolificacy, resistance to diseases and pests, and low swarming tendency.

The Bee Colony

Honey bees live in colonies. A bee colony is composed of adult bees, pupae, larves and eggs. Adult bees are of three types; queen, drones and workers. In the active season, a strong colony is roughly composed of the following components.

Queen	1	Adult
Drones	300	
Hive Workers	25,000	
Foraging workers ...	25,000	
Larvae requiring food ...	9,000	Brood
Larvae and pupae in sealed cells	20,000	
Eggs	6,000	

The Queen

The queen is the only fully sexually functional female member of the colony. She develops from a fetilized egg in a special type of cell, the royal cell. She is fed upon royal jelly, a highly nutritive substance secreted by young workers. The queen is the largest member of the bee colony and it can be easily distinguished by her elongated abdomen. Her role is principally to produce eggs. She may live for as long as ten years but, her reproductive capacity falls as she ages. At her most prolific age, when about 1 year old, the queen lays from 1,500 to 2,000 eggs daily. Besides producing eggs, the queen produces a chemical substance which prevents worker bees from becoming sexually functional females.

The Drone

Drones are male bees. They develop from infertile eggs which the queen purposefully lays in large hexagonal cells. Drones are stingless and unable to forage or perform any duty in the hive. The only function of drones is to inseminate the queen when the latter goes on her nuptial flight. Drones are much stouter than workers but shorter than the queen. When in flight drones are noisier than worker bees and they make a characteristic buzzing sound. During periods of dearth, in order to prevent undue wastage of honey, drones, are pitilessly killed by workers.

Worker Bees

Workers constitute the great mass of adult bees in a colony. Each develops from a fertilized egg in an ordinary hexagonal cell. The worker bee has an egg life of 3 days, a larval life of 6 days, a pupal life of 12 days and an adult life span varying from 6 to 8 weeks.

During the first part of her adult life, the worker does not leave the hive but is engaged only in hive duties. While staying in the hive the worker is called a nurse. She cleans the hive, removes debris and prepares the cells in which the queen lays. A worker, however, does not clean the cell from which she emerged. This is done by her older sisters.

The nurse bee feeds herself, the queen, drones, foraging workers and the unsealed larval members of the colony. She gathers honey from the comb and pours it into the mouth of the other members of the colony.

Larvae destined to becomes workers are fed upon pollen and honey but those destined to become future queens are fed upon a pharangeal secretion of the nurse called *royal jelly*, a pasty creamy white substance rich in vitamins, proteins and sugars. Its most stricking property is its ability, when used as food for a developing larva, to bring pronounced morphological and physiological differentiation which results in the formation of a perfect queen.

The nurse worker collects pollen from pollen foragers and stores them in appropriate cells. She also evaporates nectar and concentrates it into honey. Nurse bees also regulate the temperature of the hive. When it is too warm, they ventilate their hives by vibrating their wings.

As the nurse bee matures she consumes more and more honey and begins to secrete wax with which she builds the cells of the comb. Workers also build drone and queen cells, when the occasion arises.

After spending two weeks in the hive the worker begins to forage. Usually the new forager gathers pollen and it is only during the later part of her life that she forages nectar. However, this is not a rule, for, on some occasions it has been observed that some workers remain as pollen collectors while others gather only honey. Some workers gather propolis, a kind of glue which they collect from young plant buds. Propolis has an aromatic odour, melts at 65°C and dissolves in alcohol, ether and chloroform. Bees utilize propolis as an antiseptic and as glue.

Workers determine when swarming should take place. When a hive becomes overcrowded, workers construct queen cells. A number of very young larvae (1 to 2 days old) are deposited singly in such cells where they are fed royal jelly. After four days the queen cells are closed before that the required amount of royal jelly has been deposited inside. After 5½ days of development as larva, pupation occurs and 7½ days later a young queen emerges. The first queen to emerge kills all its sister queens.

During this time workers scout for a suitable site of migration. When such a site has been found the scout bees inform the colony and the parent queen is forced to swarm away accompanied by an adequate portion of the adult bee force. The colony brood and the new queen is left with the remaining portion of the adult bee force.

Swarming, from the beekeeper's point of view is a waste, for, a substantial portion of his bee force is reguarly lost. To prevent this from occuring the hive is examined from time to time during the swarming season and the queen cells removed.

Requeening

In modern beekeeping, requeening is a current practice. To maximize honey production while maintaining healthy colonies with improved apicultural standard, requeening of hives, at least every two years, is necessary. The queens presently in demand belong to the Italian race or its hybrid such as the Starline and the Midnite, all of which have proved desirable apicultural characters.

When the queen of a hive becomes less prolific, producing few workers and many drones, requeening is desirable. Usually a colony disposes itself of an old or crippled queen by a process called balling, during which a large number of aggressive workers smother the queen until she finallly dies. They then rear another queen to replace the old one. But it is not advisable to allow this to occur because:—

(a) the young queen taking the egg laying process descends from a line already bearing a poor queen and there are chances the colony will turn up to become defective;

(b) the young queen, even if descended from a good line will mate with a local drone and such a cross may produce hybrids with undesirable characters i.e. poor foraging abilities and bad temper.

Imported queen are already artificially inseminated from sperms of drones of an appropriate strain. A queen is usually sent accompanied by few workers in a small fenced box with two openings, one plugged with candy and the other closed with a piece of cork. The queen with her workers feed upon the candy during transit.

To requeen, the beekeeper opens his hive, taking the necessary precautions to avoid stinging, removes the old queen and crushed it upon the fence of the box. The closed box is then left, fence upward, in the hive. The workers of the old colony, attracted by the odour of their dead queen, angrily attacks the box without coming into direct confrontation with its content. The workers also begin eating the candy until they reach the new queen. This process may take 24 hours or more. If within 24 hours the workers have not eaten through the candy, then the beekeeper makes a perforation in the candy to help them. By the time they reach the new queen they are completely familiarized with her odour and usually they adopt her, allowing her to take over the egg laying function of the colony.

The Modern Hive

Modern hives are constructed in movable parts in order to facilitate regular inspection and manipulation during honey harvest without causing undue damage to the bees.

The hive adopted by Mauritian Bee Societies, a diagram of which is presented in Appendix I, consists of the following parts.

(a) A hive body, a wooden box holding movable racks or frames in which the brood combs are set.

(b) Supers or upper storeys to hold surplus honey.

(c) A metal queen excluder, a device placed between the hive body and the super to allow workers freedom to move but which restricts the movement of the queen to the hive body only.

(d) A wooden floor which projects beyond the hive entrance to produce a landing platform.

(e) A wooden roof to protect the hive from solar radiation, cold, etc.

(f) A wooden frame placed on top of the roof to support the cover of the hive.

(g) A galvanized tin cover to protect the hive from rain.

(h) A wooden stand.

Equipments

In addition to hives, beekeepers require a number of basic working equipment and the following is deemed necessary:—

(1) A smoker,

(2) A beekeeper's veil,

(3) A beekeeper's hat,

(4) A pair of gloves.

These equipments are important during hive inspection or honey harvest and they prevent the beekeeper from being unnecessarily stung, by aggressive bees.

The Best Place for Hives

In rural areas the best place to set hives should be the orchard, under some trees, where the bees may easily acceed to blossoms, even in poor weather conditions. In the city, the backyard garden is quite a suitable place to keep hives.

The hives should be protected from the cold prevailing wind. A hedge, a high fence or the side of a building would provide this important protection.

Hives should not be placed in an area where too much radiation from the midday sun is received. Excessive heat induces swarming and loss of bees. If trees or shrubs are not available, then som cover or boards should be provided to shelter the hives from severe solar radiation. Too much heat can reduce honey production of a hive by 40%.

Beekeeping Problems

Cyclones

All sectors of the Mauritian economy are directly or indirectly affected by cyclones. The Honey Production Industry is not spared and suffers considerably during the passage of cyclone.s

Cyclones destroy flowers, topple and drench hives causing the death of adult and immature bees. At times entire colonies are destroyed. To mitigate the effect of cyclones, bees and hives should be given protection.

As soon as a cyclone is announced, beekeepers should take precautions. The hive entrance should be plugged by some some suitable material such as foam or old cloth and the hive should be removed from the garden and stored in a dry place, then four concrete bricks (or some other suitable load) should be placed on its cover to prevent toppling. The legs of the stand should be made steadfast by suitable props. After the passage of a cyclone there always follow a dearth and the bee force may be fed on sugar solution until the appearance of fresh bloom.

Pesticides

Crop protection in Mauritius, as in other countries, depends largely upon chemicals, to which non target organisms are often susceptible. The beneficial effects of pesticides compensate enormously their pollutant effect on the environment and it is likely that agriculture will depend upon them for quite a long time.

Agropesticides are of three broad types: insecticides, for controlling insect pests; fungicides, for controlling plant pathogenic fungi; and herbicides, for controlling unwanted weeds which drain nutrients destined for desirable plant crops.

While visiting flowers for nectar, pollen or water, bees are liable to become contaminated with chemicals. The heaviest mortalities among bees result probably from indiscriminate application of pesticides to plants in bloom.

Bees forage mainly during intensive daylight. Spraying chemicals late in the evening would therefore greatly reduce the incidence of contamination. If the chemicals used have short residual action then contamination of bees can be further reduced. Spraying chemicals when there is little or no breeze also diminishes the risk of harming bees by drift. Plants in bloom should be sprayed only when unavoidable.

PART II

Pests of Bees

The following pests have been observed to associate themselves with bee hives in the country:—

(a) the wax moths,

(b) the death head moth,

(c) the bee louse,

(d) cockroaches,

(e) ants,

(f) the dragon fly,

(g) the agamid lizard,

(h) the common toad.

The wax moths (Lepidoptera, Pyralidae)

The main insect pests of hives in Mauritius are without doubt t,he wax moths, *Galleria melonella* and *Achroia grisella* Fabr. The former is known as the greater wax moth and the latter, the lesser wax moth. It is not easy to distinguish between the two species at the level of the larval stages. The caterpillar of both species tunnel through the wax of infested combs causing the death of developing bee larvae and loss of brood space.

The incidence of wax moths is high in Mauritius. This is probably because many beekeepers stack empty wax combs in the vicinity of their hives. Such empty combs act as reservoirs of wax moths which eventually spread up to their bee colonies. Hives severely infested with wax moths become inhabitable and bees finally swarm away or abscond.

To protect hives from wax moth, empty combs should be stored in suitable closed containers. All infested wax combs, frames and whole hives, free of bees obviously, should be fumigated with methyl bromide, a chemical which kills eggs, larvae and adult wax moths. Fumigation with methyl bromide, which is very toxic, should not be attempted by beekeepers without expert guidance from either the Entomology Division or the Extension Service Division of the Ministry of Agriculture, Fisheries and Natural Resources.

The Death Head Moth (Lepidoptera, Sphingidae)

Weak hives often contain the death head moth, *Acherontia atropos* L. if the breeding ground of this pest is found nearby. The larvae of the death head moth breeds in gardens containing the egg plant, *Solanum melongena* or angive, *Solanum macrocarpum* or the bittergourd, *Momordica charantia*. During the day the larvae of the death head moth hides in the ground and at night fall they migrate upon the host plant to feed on the leaves. The adult moth hovers near the hive at dawn and if the entrance is unprotected, it slides in, goes to the honey combs to feed on uncapped honey.

Acherontia atropos is parasited by *Drino atropivora, a* tachinid fly which develops in the larvae of the death head moth (Moutia & Mamet 1947). The degree of control exerted by the parasite has not been assessed.

The best method of protection against *A. atropos* is to reduce the size of the entrance of hives by means of some suitable mechanical device. One local Co-operative Society sells a cheap but efficient device to protect hives from the death head moth. This device consists of a serrated strip of galvanised tin which can easily be fitted to the hive entrance by means of a couple of nails.

The Bee Louse (Diptera, Braulidae)

The bees louse is a common pest of hives with weak colonies. The term louse, however, is a misnomer to *Braula coeca* because unlike lice this insect is not a siphonapteran but rather a wingless dipteran. The term louse is applied to it because it clings to the dorsum of the thorax of bees, especially to the queen, in a manner not unsimilar to lice behaviour.

On the queens, the presence of up to 10 lice at a time is not an uncommon phenomenon. The bee louse feeds upon royal jelly brought to the queen by nurse bees. By diminishing the food of the queen, the bee louse is thought to interfere with her fecundity. It is an extra load for her host and also a source of constant irritation. The queen and adult workers with louse are often seen to preen themselves with considerable vigour. This no doubt entails energy loss. Infested bees are often helped by their companions in sometime successful attempts to rid themselves from the louse. The larvae of the bee louse develops in the combs, where they tunnel through the wax, causing at times severe loss of brood space.

To rid the bee colony free from *B. coeca* the following method is prescribed. Cigarette tobacco are introduced in a smoker together with some old fabrics and then ignited. The smoke produced is directed into the hive through the entrance. *Braula coeca* being extremely sensitive to nicotine drops from its host and die. Bees, in general tolerate nicotine without displaying adverse effects. This operation may be repeated as frequently as infestation occurs until the colony is absolutely free from this pest.

Cockroaches (Dictyoptera, Blattidae)

Cockroaches have been observed in hives with weak colonies. Two species are found, *Periplanata americana* L. and *Periplaneta australasia* Fab.; the former being more common. Hives infested with cockroaches also contain the nymphs of the pest and purses of their immature stadia in the crevices of the comb frames. It is suspected that the cockroaches feed upon honey and the grubs of bees. Cockroaches are also known to be passive carriers of pathogens and their presence in hives is undesirable. It is not possible to keep cockroaches from hives by reducing the entrance with a device similarly to that used for keeping away *Acherontia atropos*, because cockroaches nymphs, when still young, are smaller than bees and they enter the hives easily even through reduced entrances.

Ants (Hymenoptera, Formicoidea)

Several hives are found to house ants, the most common species of which being *Monomorium floricola* Jerdon. It is not clear what the ants are up to in the hives. It would appear that they collect insect debris, broken legs, wings, etc. from the floor. Their presence does not appear to distress the bees. Stealing of wax and honey does not seem apparent.

Hives may be kept free from ants by smearing glue on the 4 feet of the stand. The glue must be replaced from time to time because dust and other materials will invariably cover the adhesive surfaces to form a bridge over which ants will cross to manifest their presence.

Anax mauritiana (Odonata, Aeshnidae)

The dragon fly, *Anax mauritiana* Ramb, is a pest of bees. It occurs in moderate numbers in the air around apiaries, where it captures workers in flight to devour them on the nearby vegetations. The dragon fly is not a very serious pest, except, however, when it captures new queens on their nuptial flight. Such a behaviour could prove a menace to the production of queens at prespective queen rearing centres.

Calotes (Agama) versicolor Daudin (Reptilia, Agamidae)

This agamid lizard is locally (but erronously) called chamaleon. In 1665 it was accidently introduced in Réunion with a consignment of sugarcane tops from Java (Vinson and vinson 1965). It was introduced in Mauritius from Réunion in 1900 by d'Emmerez de Charmoy as an insect predator.

C. versicolor is a pest of bees in Mauritius. It stalks blooming melliferous plants to capture bees when they come to forage. The predator, in camouflaged position, often lies in wait in the vicinity of hives to capture bees on their journey. It is a predominantly insectivorous species with a preference for medium size insects. A male specimen captured on the Javan shrub, *Eupatorium pallescens* in Moka, when dissected was found to contain the remain of 6 bees in its distended gizzard. A large number of the predaceous lizard living on a bee colony should have a negative impact on its honey production.

However, it is not recommended to control *C. versicolor* on account of the probable role it plays in the biological control of insect pests of medical, veterinary and agricultural importance.

Bufo regularis (Amphibia, Bufonidae)

The common or square-marked toad *Bufo regularis* is African in origin. It was privately but illegally introduced in Mauritius in 1932 from South Africa and according to Williams (1949) it plays a very small role in the control of the adult white grub *Clemora smithi* Arrow.

The common toad is to-day very numerous throughout the island. It is essentially insectivorous, swallowing indiscriminately, insect pests as well as beneficial ones, including bees.

The toad spends the greater part of the day hiding under stones, logs, fallen leaves and all sorts of debris. About one hour before twilight, they emerge in large numbers and many take position near hives to capture bees on their return journey. Some stray around the hives until several hours after dawn. Heavily laden bees are easy prey to toads. Often workers miss the landing platform and hover near the predator which gapes its mouth, quickly flicks its eversible and adhesive tongue to capture with ease the tired insects.

Bufo regularis has a good appetite for bees. Specimens captured at the site of a hive at Moka, when dissected were found to contain as many as 4 to 6 bees in the stomach. It is not advisable to destroy toads on account of their importance in the control of pestiferous insect species. To protect bees from this predator, its hiding places should be destroyed and the surroundings of hives should be kept clean.

Conclusions

In Mauritius, during the colonial epoch, apiculture was an abstruse branch of knowledge secretly guarded by a few initiated rich landlord. Some attempts were made in 1955, by the late Legislative Assembly member Dr. E. Millien to vulgarize bee farming. However, the *impetus* he tried to give to this line of development somehow lost momentum.

To-day, beekeeping is no longer a recondite subject. It is, infact, a relatively easy and valuable occupation, which if adopted as a cottage industry, would help to curb loss in foreign exchange resulting from honey and wax importation. Beekeeping involves little capital investment and almost no labour. A hive together with a bee colony costing around Rs 750 would yearly yield over its own value in honey. Besides being an activity which delights all age groups beekeeping provides for its adepts a substantial amount of energy rich and easily assimilable food.

The impact of bee farming on the environment is a positive subject which should not be underestimated. Bees being efficient natural pollinators are known to be able to increase fruit and seed production to the bearing limits of plants. The presence of bees in the environment should also serve to remind the public about the judicious use of pesticides.

The only drawback to the development of the local apicultural industry lies in the geographical position of Mauritius. The island is yearly swept by cyclones which devastate blooms and adversely affect bees. However, if bee farmers are prepared to take a minimum of precaution yearly catastrophes to their hives and bee colonies may be avoided.

The pests of bees are few and they do not present any forseeable difficulties, being all, with the exception of the wax moths, manageable with ease.

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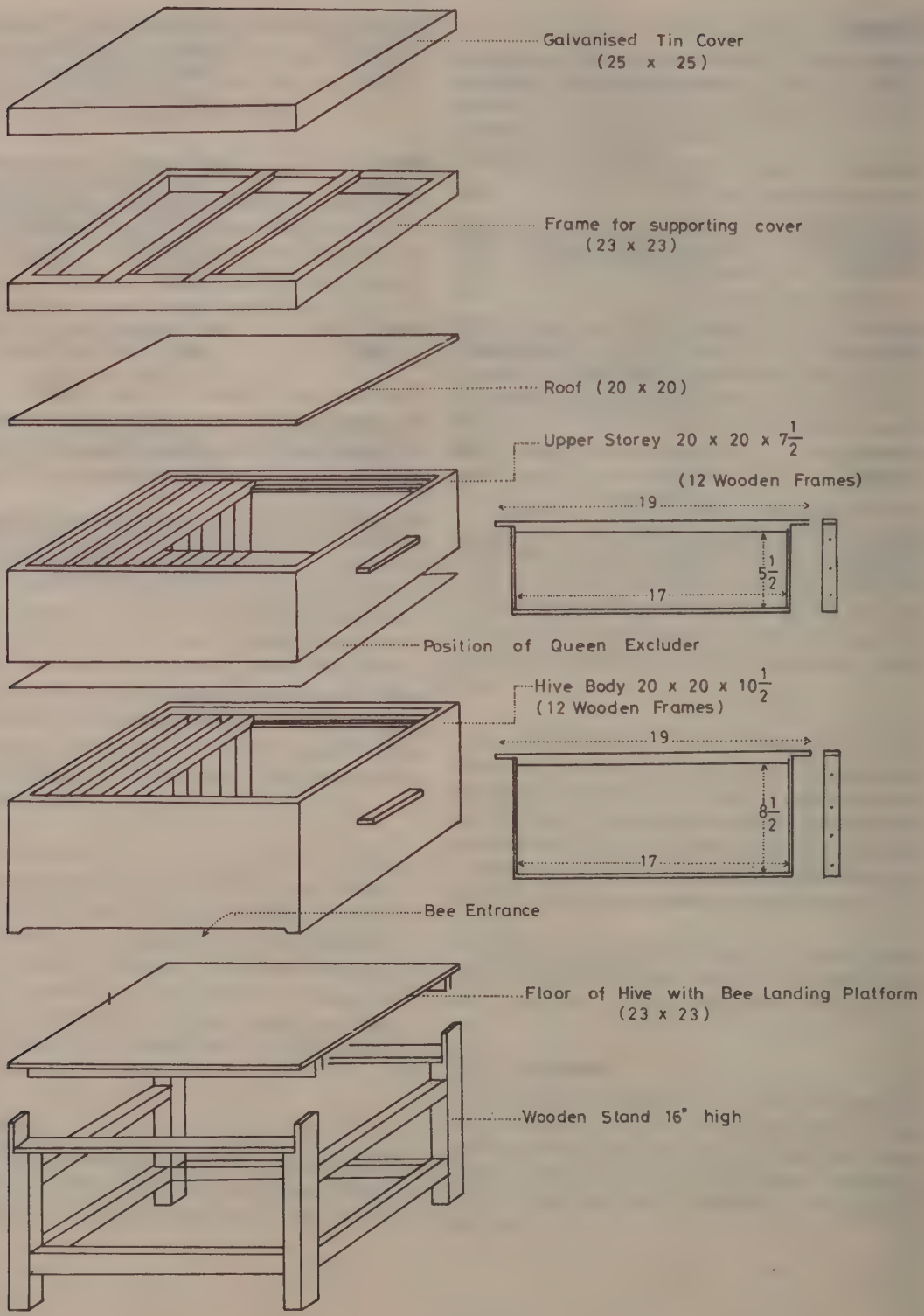
APPENDIX 1

Plan of a Modern Hive
(with dimension in inches)



The effect of plucking round length on green leaf production of tea

by

D. DUMUR & S.N. NAIDU

Scientific Officer (Agronomy)

Resumé

Un essai fut entrepris sur deux ' varietés ' de thé à la station experimentale de Wooton en vue d'étudier l'effet de la durée de l'intervalle entre les cueillettes sur la production de feuilles. Dans les deux cas les résultats demontrent qu'une augmentation substantielle de rendement découle de la réduction de l'intervalle entre les cueillettes. Cette augmentation est due principalement à un accroissement du nombre de tiges cueillies par unité de surface. Celle-ci est accompagnée d'une amélioration de la qualité de feuilles récoltées.

Summary

A trial was conducted on two tea cultivars at Wooton Tea experiment Station to investigate the effect of four plucking round lengths on the production of tea green leaf. Results suggest that for both cultivars, definite advantages may be obtained by adopting short plucking rounds, even during winter months. Higher yields are generated, arising mainly from an increase in number of plucked shoots per unit area. Moreover, a concomitant improvement in quality is evident.

Introduction

Leaf plucking is the true harvesting operation in the cultivation of tea and involves the removal of young shoots at the correct stage of growth as and when they develop above the levelled surface of the tea bush. It is a regular operation throughout the productive life of the tea bush and is also considered as a stimulus to production.

Palmer Jones (1976) identified 3 important management variables within the different plucking policies generally adopted by tea-growers viz:

(i) plucking round — the interval between harvests,

(ii) plucking standard — which relates to the size of shoot acceptable for manufacture,

(iii) plucking level, or plucking system, which relates to the size of stump left behind.

These management variables are known to affect both the yield and quality of made tea as well as the productivity of leaf pluckers.

In Mauritius, we are concerned with fine plucking standards as denoted by the collection of not more than two leaves and the bud or one ' banjhi ' leaf, i.e. a leaf with no developed bud. The frequency of plucking is generaly adjusted in such a manner as to generate a minimum of wasteful breaking back when the fine leaf is plucked. Based upon experience abroad, a plucking round not exceeding 7 days was recommended by Deane and Andrews (1959) throughout the greater part of the growing season. Since the rate of growth slows down substantially towards the end of summer, the frequency of plucking is adjusted accordingly and thus a gradual lengthening of plucking round ensues over the period April to June till the very end of the season when as much as a fortnight may elapse between rounds.

The object of this study was to verify the recommendations regarding plucking round length and to quantity the effect on yield (fresh weight basis) and quality (production of ' banjhi ' shoots) of 4 different plucking round lengths, while adopting the fine-plucking standard as generally practised in Mauritius.

Materials and Methods

A field trial was conducted on two cultivars — one seedling population of Special Assam and one clonal population of VP1H at Wooton Tea Experiment Station (elevation of 560 m above sea level; annual rainfall of 3800 mm; average daily sunshine of 6 hours; soil of Latosiloc Brown Forest type). Both cultivars were 16 years old and were last pruned in October 1980 to a height of 65 cm. Observations were thus taken on the second half of the 3-year pruning cycle, i.e. from February 1982 to June 1983. The plots were fertilised with complex NPK 22.5: 7.5 : 7.5 at the rate of 650 kgs per hectare in October and 500 kgs/ha of sulphate of ammonia in two split applications in December and February.

The experiment was laid out according to a randomised block design with 3 replicates, and the treatments under investigation were 4 plucking round lengths viz 6 days, 10 days, 14 days and 18 days respectively. At each plucking, the following data were collected: *(a)* fresh weight of plucked shoots, *(b)* weight of ' banjhi ' shoots, *(c)* weight of break-back material, *(d)* number of plucked shoots and *(e)* number of ' banjhi ' shoots. Results were analysed according to standard methods of statistical analysis.

Results and Discussion

(a) Green leaf production

Table 1 summarises the data for total annual production of green leaf on a fresh weight basis, production over the 3 peak-production months (summer) and over the 3 lowest production months (winter); the ratio *(s)* of the latter 2 figures is also presented as an index of seasonality in production.

TABLE 1

Production of green leaf (kg/ha)†

(a) Clone VP1H

Plucking round		*Annual total (a)*	*3 summer months (b)*	*3 winter months (c)*	*seasonality index(s) (d)*
6–day	...	7079.6[a]	28.55.3[a]	1083.8[a]	2.63
10–day	...	3919.2[b]	1284.9[bc]	588.9[b]	2.18
14–day	...	3138.9[b]	1150.3[c]	459.4[b]	2.50
18–day	...	3631.4[b]	1786.3[b]	465.4[b]	3.84
SE mean	...	305.5	167.7	49.6	
CV (%)	...	11.9	16.4	13.3	

(b) Special Assam

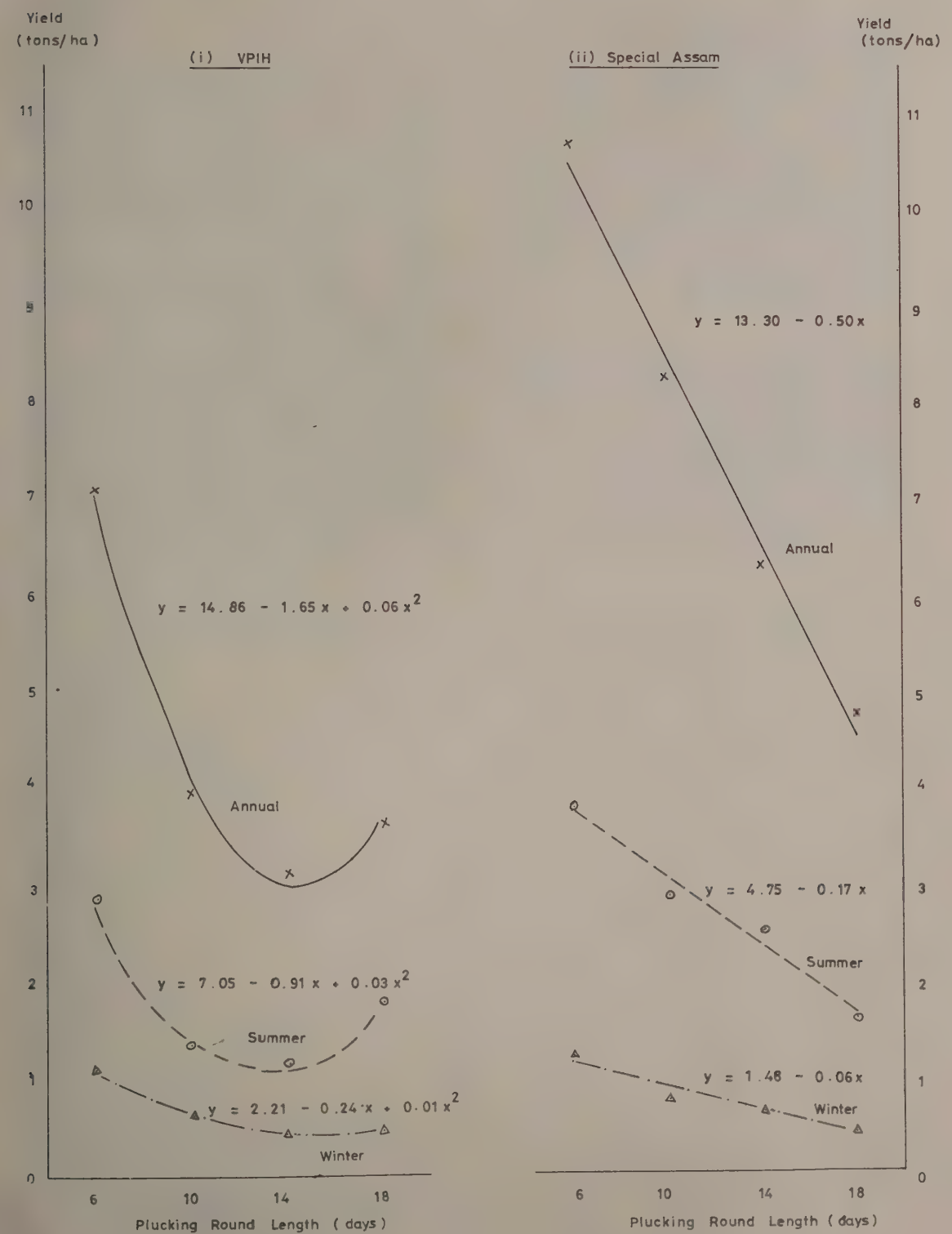
Plucking round		*Annual total (a)*	*3 summer months (b)*	*3 winter months (c)*	*seasonality index(s) (d)*
6–day	...	10,701.5[a]	3759.6[a]	1208.8[a]	3.11
10–day	...	8128.8[b]	2860.0[ab]	734.3[b]	3.89
14–day	...	6387.7[c]	2495.9[b]	618.7[cb]	4.03
18–day	...	4684.9[d]	1579.1[c]	429.5[c]	3.68
SE mean	...	484.1	147.5	70.9	
CV (%)	...	11.4	9.6	16.4	

†Means within any one column followed by the same small letter are not significantly different at 5% level. (Duncan Multiple Range Test).

Note: *(a)* annual: February 1982 — January 1983
(b) 3 summer months: February, March and April 1982
(c) 3 winter months: June, July and August 1982
(d) Seasonality index(s): $\frac{\text{3–summer month production}}{\text{3–winter month production}}$

The shortest plucking round investigated (6-days) leads to increased productivity of the tea bush for both cultivars. The above data suggest a regular linear decline in Special Assam with respect to annual, summer and winter production of green leaf (Fig. 1 *(a)*). Annual green leaf yield decreases by 16% on an average for each 4-day extension in plucking round. Such reductions in yield are cummulative over successive delays of 4 days and indicate a proportionate yield reduction with length of delay period. In the case of VP1H, the relationship is curvilinear and is indicative of substantial yield recovery at the longest plucking round (18days). Such recovery is more prominent during the summer months but in winter it is sufficient only to maintain productivity at the level of bushes plucked at 14-days intervals. Annual yield reduction is around 45% up to 10 days but longer delays entail less than proportionate reductions in yield up to 14-day plucking rounds (Fig. 1 *(b)*). Therefore, the initial delay over a 6-day plucking round is here especially critical.

Fig. 1. Effect of Plucking Round Length on Production of Green Leaf (tons/ha)



A consistent advantage is evident for cultivar Special Assam with respect to annual and summer production irrespective of the length of plucking round imposed. Differences in winter production between the two cultivars are not significant indicating that the higher annual production from Special Assam stems mainly from a comparatively higher productivity during summer months, and thereby reflecting in a higher seasonality index.

Essentially, the effect of treatments is more pronounced in summer than in winter for both cultivars. These, however, do not alter the seasonality characteristics of the cultivars, except for VP1H at the 18-day plucking round. Also, there is no indication of a shift in the period of peak production in either cultivar.

(b) Components of yield

The higher yields obtained under short plucking rounds result from the negative association of number of shoots per unit area and unit plucked shoot weight. The influence of plucking round length on number of plucked shoots is similar to that on total green leaf production for both cultivars (Table 2.). In the case of mean shoot weight, a direct linear relationship exists with length of plucking round i.e. longer plucking rounds bring about heavier plucked shoots for both cultivars. (Fig. 2 *(a)* and 2 *(b)*).

However, the inflence of longer plucking round towards an increase in unit weight of plucked shoot is not sufficient to offset the effect on yield of the concomitant reduction in number of plucked shoots, so that an overall negative effect is maintained for long plucking rounds.

Fig. 2 (a). Effect of Plucking Round Length on Number of Plucked Shoots /ha

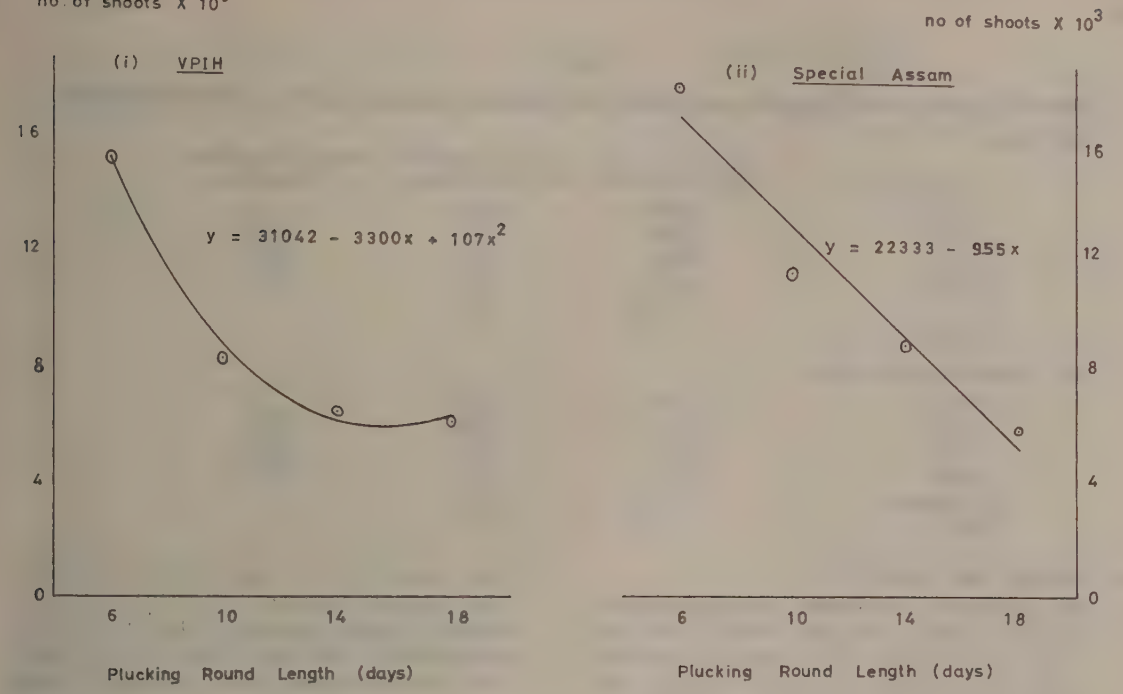


Fig. 2(b) Effect of Plucking Round Length on Weight of 100 Plucked Shoots

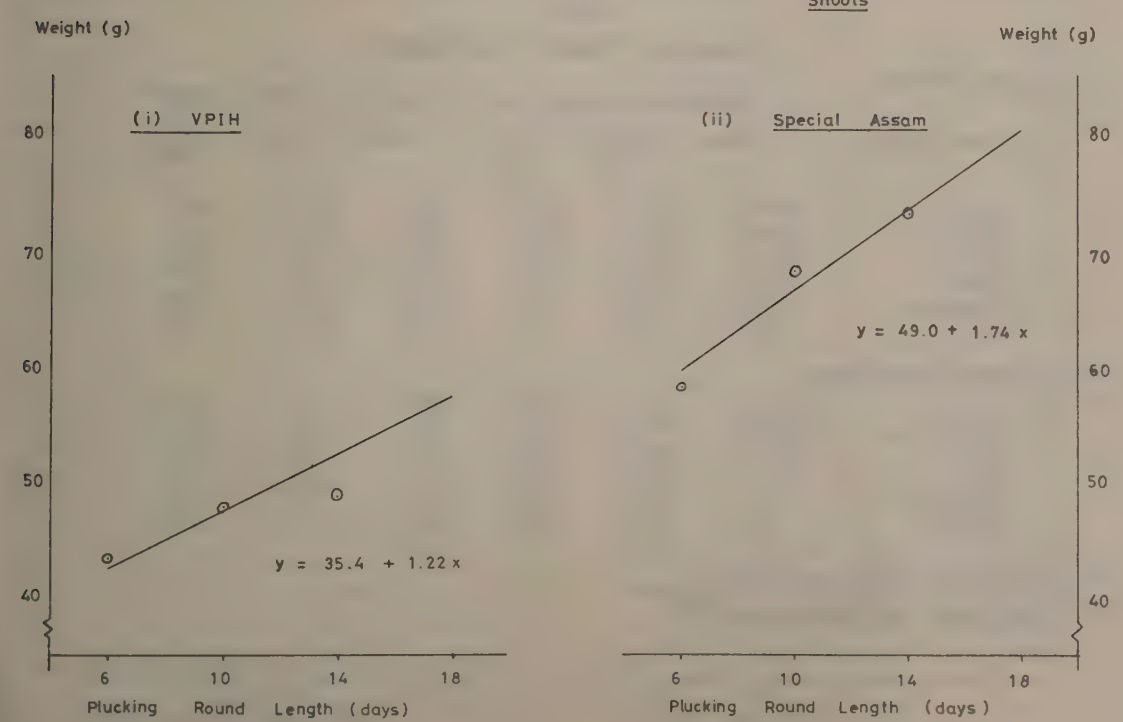


TABLE 2

Effects of plucking round length on components of tea green leaf yield and break-back material produced

(a) Cultivar VP1H

Plucking round	*Number of plucked shoots/ha per annum*	*Mean weight of 100 plucked shoots (g)*	*Weight of break-back kg/ha/annum*
6–day ...	15294[a]	43.5[c]	0
10–day ...	8139[b]	48.3[b]	1255.5
14–day ...	6410[b]	49.0[b]	1248.6
18–day ...	6098[b]	59.6[a]	1701.3
SE ...	692.8	0.60	
CV (%) ...	13.2	2.07	

(b) Cultivar Special Assam

6–day ...	17754[a]	58.3[c]	0
10–day ...	11172[b]	68.4[b]	2246.2
14–day ...	8754[c]	73.1[b]	2189.7
18–day ...	5832[d]	80.0[a]	2149.4
SE (mean) ...	675.3	1.83	
CV (%) ...	10.7	4.54	

(c) 'Banjhi' shoot production

The production of 'banjhi' shoots during the different periods of the year (Table 3) indicates a constant decline with increasing plucking round length for Special Assam; 'banjhi' production during summer and winter months is not unduly influenced by plucking interval and the decline occurs principally during the other months of the year (Fig. 3). However, when 'banjhi' production is assessed as a percentage of total production, which is indicative of the quality of the field output, the data suggest that improved quality of leaf is obtained during the summer months. But irrespective of season, the quality of green leaf produced deteriorates with increasing plucking round length.

TABLE 3

Production of " banjhi " shoots (kg/ha)

(a) Cultiver VP1H

Plucking round	*Banjhi shoot production (kg/ha)*			*Banjhi % green leaf production*		
	Annual (a)	*3 summer months (b)*	*3 winter months (c)*	*Annual*	*3 summer months*	*3 winter months*
6–day ...	2644.9[a]	725.2[a]	417.9[a]	37.5[b]	22.5[b]	38.7[b]
10–day ...	1646.0[b]	367.3[b]	267.7[b]	41.9[ab]	27.0[ab]	45.7[ab]
14–day ...	1565.5[b]	426.3[b]	270.7[b]	49.4[a]	37.0[ab]	58.5[a]
18–day ...	1702.6[b]	777.1[a]	226.0[b]	47.3[ab]	44.4[a]	49.0[ab]
SE (mean) ...	151.1	53.1	29.7	2.79	5.47	3.80
CV (%) ...	14.0	17.3	17.4	10.97	28.94	13.73

(b) Cultivar Special Assam

6–day ...	2139.8[a]	462.1[a]	242.3[a]	20.7[c]	12.2[b]	20.2[b]
10–day ...	2008.1[a]	445.8[a]	171.4[ab]	26.3[bc]	15.6[b]	23.2[b]
14–day ...	1974.0[a]	462.1[a]	140.0[b]	30.7[ab]	18.4[b]	22.2[b]
18–day ...	1556.3[a]	392.2[a]	159.6[ab]	33.7[a]	25.4[a]	37.0[a]
SE (mean) ...	174.6	49.3	26.4	1.62	1.97	2.96
CV (%) ...	15.7	19.4	25.6	10.1	19.0	19.98

(a) annual: February 1982 to January 1983
(b) 3 summer months: February, March and April 1982
(c) 3 winter months: June, July and August 1982.

Fig. 3(a) Production of Banjhi Shoots (tons/ha)

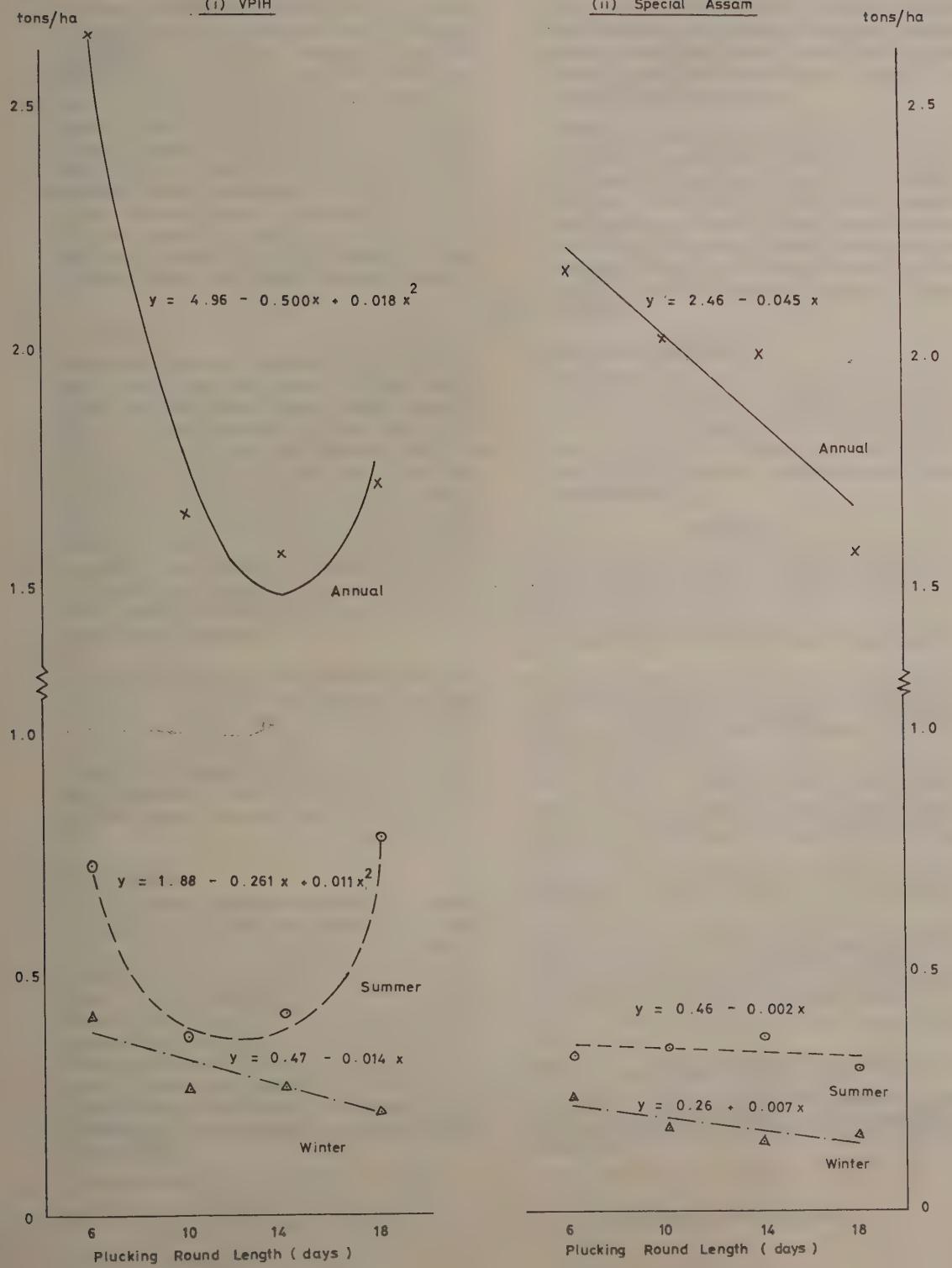
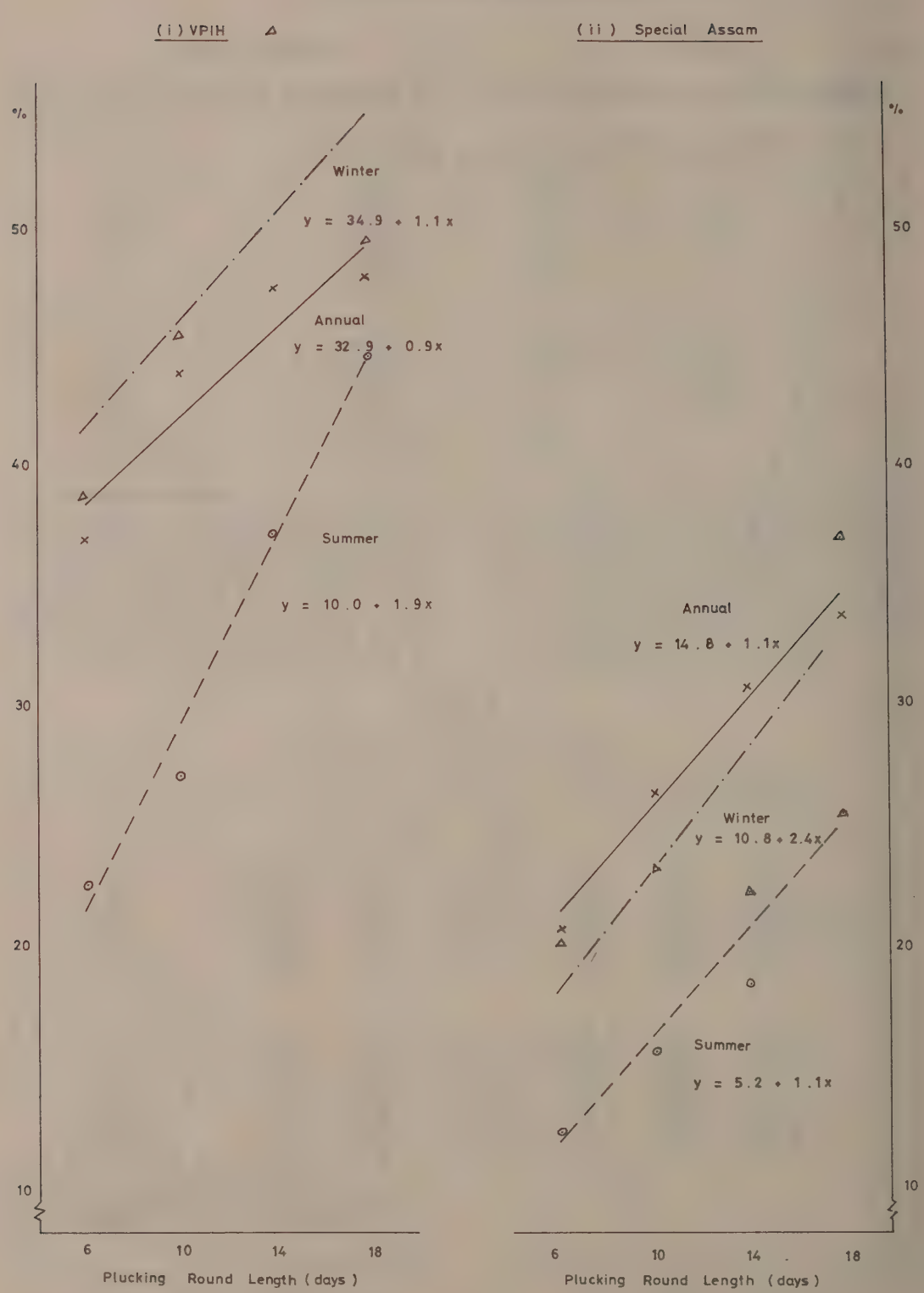


Fig. 3(b) . Banjhi % Green Leaf Production



For clone VP1H, the total weight of banjhi shoots produced follows a curvilinear trend with respect to plucking round length, matching closely the corresponding relationship with respect to total economic yield. Data on annual production suggest a higher percentage by weight of 'banjhi' shoots compared to cultivar Special Assam; at best, with short plucking round length, banjhi% economic yields may reach as high as 40% during winter coming down to around 25% during summer months. A decline in leaf quality is similarly observed in VP1H except for some recovery beyond the 14–day plucking interval.

(d) Break-back

During the plucking operation, shoots with two leaves and a bud are tipped off the plucking table; for overgrown shoots which invariably arise, it is recommended that after the terminal part has been plucked, any left-over portion of such shoots be removed as break-back to the level of the plucking table, and discarded. The break-back involves a substantial element of wastage of the resources of the tea bush which could have potentially contributed to economic yield; further it is wasteful of pluckers' time as considerable effort need to be spent by pluckers on breaking back during the harvest.

At plucking rounds of 6 days, the need for break-back does not arise in both cultivars; any delay beyond 6 days necessitates such an operation, and it is observed that on average annually, no less than 1250 kg/ha of break-back material need to be discarded in the case of VP1H and as much as 2000 kg/ha in Special Assam. (Table 2).

CONCLUSION

Results indicate definite advantages for a 6–day plucking round length with respect to quantity and quantity of green leaf produced, both of which are desirable at planter and national levels, thus supporting Deane and Andrew's (1959) recommendations. However, the present investigation does not show any benefit in lengthening plucking rounds to adjust for the naturally slower rate of shoot regeneration by tea bushes in winter. Indeed, the data observed suggest that the advantage of 6–day interval is maintained during such periods.

The extra yields generated by short plucking round length arise mainly from an increased number of plucked shoots, which thus confirms plucking as an effective stimulus to enhance the productivity of the tea bush.

It may be argued that such increases in green leaf production would entail additional labour input which could offset the resulting financial benefits. However, the adoption of short plucking rounds would eliminate breaking back as an operation and lead to improved plucker productivity so that the increased production may be harvested with less than proportionate increases in human resources.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the Divisional Scientific Officer (Agronomy) and staff of Wooton Tea Experiment Station for the facilities provided. The assistance at field level by Senior Field Assistant A. Fowdur is particularly acknowledged.

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Effects of planting date on five cultivars of Snap Bean *(Phaseolus vulgaris)*

by

V. VEERAPA & I. RAJKOMAR

Scientific Officer (Horticulture) and Divisional Scientific Officer (Horticulture) respectively.

Resumé

Durant la période 1981–83, des essais de variétés dates de plantation à trois sites différents n'ont revélé aucune différence significative dans le rendement des variétés. Les semis de Mai-Juin (début d'hiver) ont donné les meilleurs rendements en gousses vertes et un nombre supérieur de gousses par plante. Les plantations effectuées en Octobre-Novembre (été) furent particulièrement sensibles à la rouille (**Uromyces appendiculatus**).

Summary

In snap bean cultivar x planting date trials at three different planting sites over the period 1981–83, no significant differences in yield and in the number of pods per plant were observed among the cultivars. The highest number of pods per plant, hence the best yields were obtained with May-June (early winter) sowings, whilst October-November (summer) sowings were prone to rust (**Uromyces appendiculatus**) *attack.*

Introduction

Yield of snap or French bean *(Phaseolus vulgaris* L.) seems to be largely dependent on temperature. SIMS and HARRINGTON (1968) observed that a range of temperature from 18°C to 26°C was the most favourable for germination, growth and yield. CURWEN (1969) found that, at flowering, temperature above 30°C coupled with low soil moisture caused imperfect fertilisation. High night temperature was shown to stimulate respiration rate, depleting the carbohydrate reserves, thus reducing pod set and retention (MACK and SINGH, 1969). Again, high night temperature (about 27°C) were also reported by FISHER AND WEAVER (1974) to be deleterious to pod set and retention, although they promoted flower opening.

In Mauritius, mean temperature vary from about 16°C to 22°C on the Central Plateau and from 21° to 27°C at sea level. The local prevailing temperature therefore appears to be suited for bean cultivation, and in fact, green bean is being produced year round (VEERAPA et al, 1983). However, little research has been conducted to quantify the yields obtainable in our agro-climatic conditions at different seasons using different varieties. The objective of the present study was therefore to determine the effects of several planting dates on the yield bean and yield components of five/cultivars.

Materials and Methods

The experiments were sited at Central Experiment Station Réduit (330m elevation, soil type low Humic Latosol), Plaisance Experiment Station (15m altitude, soil type latosolic Reddish Prairie) and Barkly Experiment Station (225m elevation; soil type Latosolic Reddish Prairie). Planting dates and cultivars are shown in tables I to IV. A randomized Complete Block design was used with two replicates, treatments consisting of the factorial combinations of the four planting dates and four varieties in 1981, three planting dates and four varieties in 1982, three planting dates and four varieties in 1983. Plot size was 3×2m. Each plot was made of four rows each 3m long and spaced 40 cm apart, seeds being sown 10 cm apart in the row. A dressing of 75 kg P_2O_5/ha as triple super phosphate and 90 kg K_2O/ha as muriate of potash was applied prior to sowing. Two weeks after seed germination, a side dressing of sulphate of amonia at 120 kg N/ha was made. Data were gathered from the two middle rows of each plot. Tender pods were picked twice a week during harvests and the results were statistically analysed.

Results and Discussion

Yield of green pods

Results, in tables I to IV show that sowing on the third week of June or early winter was the optimum planting date at Réduit, Plaisance and Barkly. By October/November plantings gave significantly lower ($P=0.01$) yields in 1981 at Réduit and Plaisance (Tables I and II). This might have been due to a high incidence of rust *(Uromyces appendiculatus)* at the onset of flowering causing premature senescence of the plants.

It is known that rust is more pronounced in high humidity conditions such as those prevailing during mid to late summer. The drought conditions which prevailed during 1983 was also responsible for the low yields at Barkly (Table IV).

Yield trends are illustrated in figure 1 which also show that the winter planted crops pass through a relatively lower temperature range throughout their crop cycle. MACK and SINGH (1969) reported that temperature exceeding 24°C could cause reduction of about 3.5% in pod set for each degree rise up to 36.7°C. These facts help to explain the higher winter yields.

There was no significant difference among the different varieties tested. HARDWICK (1972) compared French bean (*Phaseolus vulgaris* L.) to runner bean (*Phaseolus coccineus* L.) and concluded that yield difference were not due to varieties, but to different temperature prevailing at different planting dates.

Number of pods per plant, days to 50% flowering and last harvest

There is a highly positive correlation (r=0.98)** between yield and number of pods per plant. This relation is expressed by $Y=0.493x + 1.12$ where y=yield of green bean pods (t/ha) and x=number of pods per plant. Significantly lower (P=0.01) number of pods per plant were recorded for the October/November sowings and thus the low yield obtained during the summer plantings.

At each planting date variety Noorinbee flowered later than the other varieties causing a delay in its harvest. This characteristic of Noorinbee was reported by VENCATASAMY and RUHEE (1981).

The June plantations were observed to increase the harvesting period, which contributed to a higher yield.

Thus it appears that bean can be satisfactorily grown in Mauritius throughout the year if pests and diseases are kept under control. However early winter sowings will produce higher yields, partly due to the lower temperature prevailing throughout the crop cycle and to the longer harvesting period.

**Significant at 1% level (42 d.f...)

Fig. I- Mean yields of Beans at four localities under different temperature regimes

25.5°C	23.7°C	22.6°C	21.4°C	19.6°C	19.4°C	20.1°C	21.8°C	23.5°C	24.4°C Mean temparature at Barkly for 1983
24.0°C	24.2°C	22.5°C	21.0°C	20.0°C	19.2°C	20.4°C	21.4°C	21.0°C	22.2°C Mean temperature at Reduit for 1982
26.3°C	25.5°C	23.9°C	22.0°C	20.6°C	20.9°C	21.7°C	23.2°C	24.0°C	25.4°C Mean temperature at Plaisance for 1981
25.2°C	23.2°C	21.2°C	19.9°C	18.7°C	20.5°C	21.0°C	22.4°C	22.8°C	25.5°C Mean temperature at Reduit for 1981

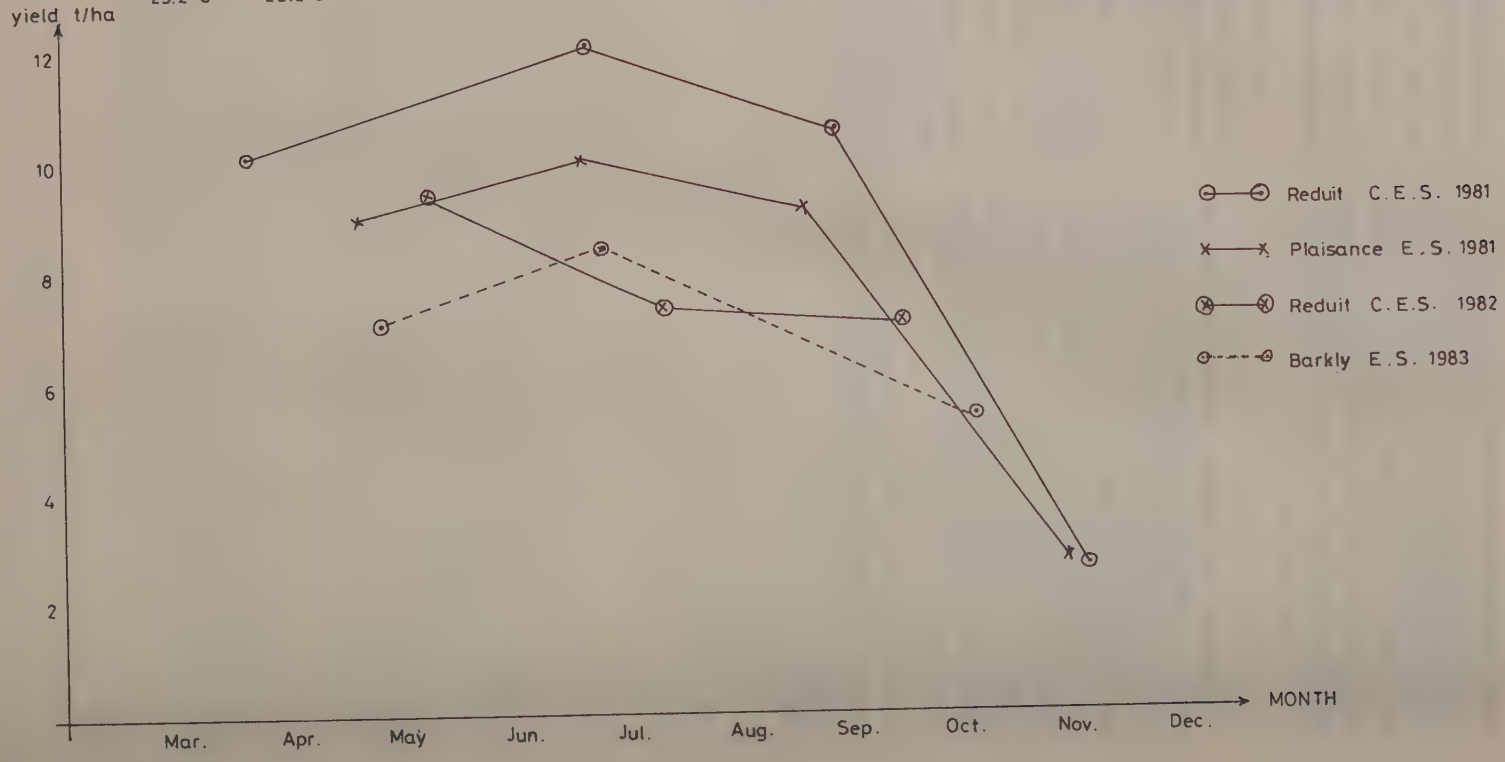

TABLE I

MEAN YIELD OF GREEN BEAN PODS, NO. OF PODS PER PLANT, DAYS TO 50% FLOWERING AND DAYS TO LAST HARVEST OF 4 CULTIVARS OF BEAN PLANTED ON 4 DATES AT REDUIT CENTRAL EXPERIMENT STATION

Varieties	*Planting date 18.3.81*				*Planting date 20.6.81*				*Planting date 27.8.81*				*Planting date 4.11.81*			
	Yield (t/ha)	*No. of pods per plant*	*Days to 50% flowering*	*Days to last harvest*	*Yield (t/ha)*	*No. of pods per plant*	*Days to 50% flowering*	*Days to last harvest*	*Yield (t/ha)*	*No. of pods per plant*	*Days to 50% flowering*	*Days to last harvest*	*Yield (t/ha)*	*No. of pods per plant*	*Days to 50% flowering*	*Days to last harvest*
Long Tom ...	1.1	16.5	39	61	12.8	18.6	38	62	11.2	17.5	39	62	3.1	5.4	40	63
Noorimbee ...	0.1	15.4	46	70	12.7	17.5	45	73	10.8	16.6	45	74	2.9	4.9	46	73
Pioneer ...	0.4	15.3	38	60	12.6	16.6	38	62	10.9	15.1	39	62	2.3	3.6	40	63
Victory ...	8.9	12.8	39	62	9.8	14.7	39	63	9.0	13.4	40	62	2.1	3.5	41	64
Mean ...	0.1	15.0	40.4	63.3	12.0	16.9	10.0	65.0	10.5	10.4	40.8	65.0	2.6	4.4	41.8	66.5
S.E. of mean ...	0.46	0.87	1.85	2.29	0.73	0.88	1.68	2.68	0.50	0.82	1.44	2.92	0.23	0.52	1.45	2.48

TABLE II

MEAN YIELD OF GREEN BEAN PODS, NO. OF PODS PER PLANT, DAYS TO 50% FLOWERING AND DAYS TO LAST HARVEST OF 4 CULTIVARS OF BEAN PLANTED ON 4 DATES AT PLAISANCE EXPERIMENT STATION

Varieties	*Planting date 17.4.81*				*Planting date 17.6.84*				*Planting date 18.8.81*				*Planting date 31.10.81*			
	Yield (t/ha)	*No. of pods per plant*	*Days to 50% flowering*	*Days to last harvest*	*Yield (t/ha)*	*No. of pods per plant*	*Days to 50% flowering*	*Days to last harvest*	*Yield (t/ha)*	*No. of pods per plant*	*Days to 50% flowering*	*Days to last harvest*	*Yield (t/ha)*	*No. of pods per plant*	*Days to 50% flowering*	*Days to last harvest*
Long Tom ...	9.8	14.6	38	60	12.3	16.6	39	62	9.9	14.1	40	61	1.9	5.7	38	64
Noorimbee ...	8.9	12.8	45	70	11.4	11.2	46	72	9.7	13.9	45	70	2.8	4.9	44	72
Pioneer ...	8.8	12.8	39	61	12.7	16.0	40	63	8.9	12.8	41	62	2.8	4.8	39	63
Victory ...	7.9	11.5	38	61	10.0	14.9	39	61	8.0	12.7	40	60	2.5	4.8	38	63
Mean ...	8.9	12.9	40.0	63.0	11.6	15.4	41.0	64.5	9.1	13.3	41.5	63.3	2.8	5.1	39.8	65.5
S.E. of mean ...	0.39	0.66	1.68	2.34	0.60	0.58	1.69	2.53	0.43	0.52	1.19	2.29	0.09	0.25	1.45	2.62

TABLE III

MEAN YIELD OF GREEN BEANS, No. OF PODS PER PLANT, DAYS TO 50% FLOWERING AND DAYS TO LAST HARVEST OF 4 VARIETIES OF BEAN AT 3 DATES AT REDUIT CENTRAL EXPERIMENT STATION

Varieties	Planting Date 7.5.82				Planting Date 9.7.82				Planting Date 15.9.82			
	Yield (t/ha)	No. of pods per plant	Days to 50% flowering	Days to last harvest	Yield (t/ha)	No. of pods per plant	Days to 50% flowering	Days to last harvest	Yield (t/ha)	No. of pods per plant	Days to 50% flowering	Days to last harvest
Long Tom ...	9. 9	14. 1	38	61	7. 6	12. 9	39	59	8. 5	13. 6	37	63
Norinbee ...	9. 7	13. 2	47	72	7. 4	12. 1	46	70	8. 3	12. 9	46	74
Pioneer ...	9. 0	13. 3	38	61	7. 4	12. 8	39	60	6. 1	10. 8	38	62
Local Red ...	8. 6	12. 7	39	61	6. 6	11. 7	39	59	5. 1	9.70	37	63
Mean ...	9. 3	13. 3	40.5	63.8	7. 3	12. 4	40.8	62.0	7. 0	11. 8	39.5	65.5
S.E. of Mean ...	0.27	0.54	1.58	2.35	0.21	0.24	1.65	2.53	0.33	0.98	14.9	2.61

TABLE IV

MEAN YIELD OF GREEN BEAN, No. OF PODS PER PLANT, DAYS TO 50% FLOWERING AND DAYS TO LAST HARVEST OF 4 CULTIVARS OF BEAN PLANTED ON 3 DATES AT BARKLY EXPERIMENT STATION

Varieties	Planting Date 25.4.83				Planting Date 24.6.83				Planting Date 5.10.83			
	Yield (t/ha)	No. of pods per plant	Days to 50% flowering	Days to last harvest	Yield (t/ha)	No. of pods per plant	Days to 50% flowering	Days to last harvest	Yield (t/ha)	No. of pods per plant	Days to 50% flowering	Days to last harvest
Long Tom ...	7. 8	11. 6	39	61	9. 1	17. 3	37	63	5. 9	9. 4	38	59
Norimbee ...	7. 6	11. 4	45	70	8. 4	16. 9	45	72	5. 6	9. 3	46	72
Pioneer ...	6. 8	10. 9	40	62	8. 4	15. 8	38	62	4. 9	8. 4	40	61
Contender ...	5. 9	9. 8	41	61	7. 8	14. 9	39	61	4. 8	8. 1	39	60
Mean ...	7.01	10. 9	41. 3	63.5	8. 4	16.2	39.8	64.5	5. 3	8. 8	40. 8	63.0
S.E. of Mean ...	0.86	0.81	2.63	2.28	0.53	1.09	3.59	5.07	0.54	0.58	3.59	6.06

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Biogas Production from Livestock Waste

By A. R. Satar & S. Purmanund

Respectively Principal Agricultural Engineer and Agricultural Engineer

Summary

This article features the general aspects of biogas productions, viz. Conditions for optimum gas production, design and setting up of 2m³ biogas per day plant.

Résumé

Cet article décrit les aspects principaux de la production de biogaz; c.à.d. les conditions optimales pour la production du gaz et l'étude pour l'implantation d'une unité de 2m³/jour.

1. Introduction

The world wide shortage of conventional sources of energy has recently revived much interest in the research and development of renewable sources of energy. One such renewable source of energy is that obtained by the anaerobic decomposition of biomass, viz. biogas.

Biogas technology is a simple technology that does not require much skill in its application, hence its suitability and popularity in villages of some underdeveloped countries.

Applied biogas technology in Mauritius is recent and dates back to 1983 with the setting up of a split type horizontal plant of capacity 100m³ biogas per day by the Engineering Division of the Ministry of Agriculture and a family size plant by the Rural Development Unit.

2. Sources of Biogas

Biogas is obtained by the anaerobic fermentation of organic materials. All organic materials, with the exception of mineral oils and lignin, are suitable for the production of biogas. Animal waste, human waste and agricultural residues are the usual sources of raw materials for the production of biogas.

Biogas is mainly a mixture of methane and carbon dioxide. The methane content of biogas varies from 50% to 60% and that of carbon dioxide from 35% to 40% Hydrogen sulphide content in the gas is about 0.2%.

Sources of raw materials and biogas yield are as given in table I. The figures given are approximate and may vary with the size of the animal, type of feed, etc.

TABLE I

*Biogas Yield From Diffrent Raw Materials (³)**

Source	*Availability of waste per day (kg)*	*vol. of gas per Kg (m^3)*	*vol. of gas per animal per day (m^3)*
cattle (medium size) ...	10	0.0368	0.368
Night soil ...	0.4	0.0708	0.028
Pig (45 kg wt) ...	2.25	0.0793	0.178
Poultry bird (2kg wt) ...	0.18	0.062	0.011

*Numbers in parentheses refer to the appended references.

The biogas yield and fuel value of water hyacinth and cattle dung is compared in table II

TABLE II

Comparison of Biogas Production with Water Hyacinth and Cattle Dung (³)

Raw material	*Volume of biogas per kg of wet mass (m^3)*	*Fuel value of biogas (K.cal. per m^3)*	*Net fuel value (K.cal/Kg of wet mass)*
Water Hyacinth (leaf) ...	0.053	2600	137.00
Cow dung ...	0.037	2660	98.40

3. Factors Influencing Biogas Production

Biogas generation is a microbial activity. Optimum gas production is obtained by providing suitable conditions to the gas producing bacteria to thrive. These bacteria generally known as "methane generating bacteria" are very sensitive to environmental conditions in the digester.

The main factors influencing biogas production are:

(a) Strict anaerobic condition.

Anaerobic condition in the digester is a must as even traces of oxygen affect the methanogenic bacteria and inhibit biogas production. Thus a well sealed digester is a prerequisite for optimum gas production.

(b) Suitable raw material

For satisfactory gas production the substrate must have the following prerequisites:

(i) Balanced carbon and nitrogen ratio:

The bacteria consumes carbon for energy and nitrogen for building their cell structure. A carbon nitrogen ratio of 25 to 30: 1 is essential for satisfactory gas production because the bacteria consumes carbon about 25 times faster than nitrogen in the digestion process. Therefore care is taken to mix nitrogen rich and nitrogen poor materials to achieve the above proportion.

The carbon nitrogen ratio of some raw materials used in the production of biogas is given in table III

TABLE III

The C/N Ratio of Commonly Available Rural Raw Materials for Biogas Fermentation [2] *(Approx. value)*

Raw materials	*C (dry wt %)*	*N (dry wt %)*	*C/N ratio*
Stalks:			
Straw (wheat) ...	46	0.53	87:1
Straw (rice) ...	42	0.63	67:1
Stalks (corn) ...	40	0.75	53:1
Fallen leaves ...	41	1.00	47:1
Stalks (soy bean) ...	41	1.30	32:1
Weeds ...	14	0.54	27:1
Stalks and leaves (peanut) ...	11	0.59	19:1
Manure			
Sheep ...	16	0.55	29:1
Cattle ...	7.3	0.29	25:1
Horse ...	10	0.42	25:1
Swine ...	7.8	0.65	13:1
Human faeces ...	2.5	0.85	29:1

(ii) *Proper dilution of raw material*

Optimum gas yield is in the range of 7.5% to 10% dry matter [1]. Thus, for example, fresh cowdung has a dry matter content of about 18%, to achieve 9% dry matter content the cowdung is mixed with equal volume of water.

(iii) *Pre-treatment of raw material*

Crop residues, because of their waxy layer (lignin), are not readily digested by the bacteria. These materials when fed into the digester without pretreatment results in low and slow yield of biogas.

These materials are pretreated by feeding to livestock or by composting. The waxy layer of the raw materials is disintegrated and the cellulose become soft and hence susceptible to bacterial digestion.

(c) Optimum temperature:

Efficient bacterial activity is a function of the digester temperature. Bacterial activity goes down during winter hence gas production is low.

There are two temperature ranges through which bacterial activities are most efficient and biogas production optimum. These are the mesophilic temperature range about 35°C and thermophilic temperature range about 55°C.

At the mesophilic temperature range for anaerobic digestion of cowdung the yield in biogas is about four times than the yield at room temperature 21°C[1].

(d) Optimum pH

Bacterial activity in the digester is best at about neutral pH. Biogas fermentation is normal between pH 6.6 to 8.0 pH 6.2 is toxic. Low pH results from mismanagement of the substrate such as incorrect raw material mix leading to unbalanced digestion.

(e) Stirring of the substrate

Stirring ensures good distribution of the raw material in the digester. It prevents crust formation on top of the slurry and thus promotes gas formation.

(f) Internal pressure

High internal pressure of the digester dedecreases gas production. Internal pressure of 40-50 cm water column has no effect on gas production, but at internal pressure of 60-90 cms water column gas production is decreased. ([2])

(g) Retention Time

Retention time is the time during which the substrate resides in the digester.

The amount of gas produced per unit of dry matter and per unit of organic matter increases with retention time ([5]). The daily gas production per unit of digester volume is inversely proportional to retention time ([4]). Thus for producing a unit volume of gas the volume of digester is smaller when shorter retention time is selected. However the daily quantity of manure to be fed to the digester is higher for shorter retention time.

Usually retention time is between 30 to 50 days, depending on economic aspect and availability of raw material.

4. Biogas Plants Classification

A biogas plant consists of two main units, a digester in which anaerobic fermentation of the substrate produces biogas and a gas holder where the biogas produced is stored pending its use.

Biogas plants may be classified as follows:—

(i) *According to constructional features*

The plants are designated as integrated or split type. In the integrated type the digester and the gas holder form one unit. In the split type the gas holder and the digester are separate units.

The plants are further sub-classified as vertical or horizontal. The vertical type is characterised by a deep cylindrical digester where as the horizontal type has a shallow rectangular digester.

(ii) *According to method of charging the digester*

Two types are designated, continuous and batch type. in the continuous type the digester is fed daily with a fresh amount of slurry and simultaneously the same amount of digested slurry leaves the digester.

In the batch type the digester is seeded, filled to capacity with slurry and then sealed. It is allowed to produce biogas for a fixed period after which the digester is opened and the decomposed slurry (sludge) is removed.

5. Biogas Plants Evolution in Mauritius

Application of biogas technology dates back to 1983 and is still in the latent stage. About a dozen plant of the Khadi Village Industries and Commission (KVIC) have been set up by the Rural Development Unit on different parts of the island. The Ministry of Agriculture's contributions are as follows:

(i) Setting up of a 100m^3 gas per day plant at the livestock breeding station at Richelieu for the generation of electricity —(1983).

(ii) Setting up of a 2m^3 biogas per day plant at Petite Rivière—(Tanzanian type with oil drum gas holders)—1984.

(iii) Setting up a 4m^3 biogas per day plant at Centre de Flacq—(KVIC Model)—1984.

(iv) Setting up of two horizontal digesters (each of 70m^3 biogas per day capacity) presently in use as pollution control plants for piggeries at Prime Farms, Belle-Vue—1983/84.

Characteristics, performance and viability of these plants will be treated in another paper.

The University of Mauritius in its biogas research program which started in 1982 is currently coming out with valuable informations on application of this technology in the local context.

6. The K.V.I.C. Biogas Plant

This plant which is a popular and much proven model in India is being popularised by the R.D.U. pending the development of a cheaper and worthy local model.

It is a continuous vertical integrated plant with a mildsteel gas holder which moves up and down the digester through central guide frames.

This model is more suitable under the following conditions:

(i) Low water table

(ii) Flood level low enough not to enter the digester

(iii) Digester pit excavation not costly.

7. The Setting up of a Biogas Plant

The factors influencing the design and setting up of a biogas plant are:

(i) *Availability of raw material*

The main raw materials input for a small continuous type biogas plant are animal waste and water. Crop residues may be added as a supplement to animal waste in controlled quantity only. The untreated crop residues because of their high lignin content and hence low bacterial digestibility may clog the continuous type digester.

In batch type digesters crop residues mixed with animal waste are advantageously used in the production of biogas(4).

Availability of enough raw material to meet the plant requirement must be ascertained before setting up the biogas plant.

(ii) *Location of the biogas plant*

The plant should be located on higher grounds to prevent it from being flooded and should be at least 15 metres from drinking water well. It should receive maximum sunlight to maintain the temperature of the digester for steady gas production. It should be located as near as possible to the source of raw material (cattle shed) and point of utilisation (kitchen).

(iii) Size of the plant

The size of the plant is determined in relation to the energy needed and availability of raw materials. The average requirement per person per day for cooking varies from 0 28 to 0.33m³ biogas.

The daily requirement in effective energy for an average family in Mauritius is 15.8 MJ, at a stove efficiency of 65% and heat content of 4,000 cal/l the daily biogas requirement is 1,500l(1).

Hence a 2m³ biogas per day plant should amply suffice an average Mauritian family for all its cooking purposes.

Plant Design (2m³ biogas/day—cowdung)

In the design of the plant the following factors need be considered.

(i) Type of raw material to be used and volume of gas produced per unit weight. For cow dung 1 kg of fresh dung produces 0.036 m³ of biogas.

(ii) Retention time—Normally 50 days

(iii) Temperature—optimum 35°C

(iv) Solid concentration—6% to 11%(4)

Normally cowdung: water=1:1—(i.e. 9% dry matter is taken).

Calculations

(i) Digester volume — Dv

Assuming density of fresh dung = 1120 kg/m³

let volume of gas to be produced daily = Vm³

let the retention time = T days

Daily input of dung $= \frac{V}{0.036}$ kg $= \frac{V}{0.036 \times 1120}$ m³

For a dung: water = 1: 1

Daily input of slurry $= \frac{2V}{0.036 \times 1120}$ m³

Volume of the digester for retention time of T days

$$Dv = \frac{2VT}{0.036 \times 1120} m^3 = \frac{2VT}{40.32} m^3 = \frac{2VT}{40} \text{ (say)}$$

Thus for a 2m³ biogas/day plant with 50 days retention time

$$\text{Digester volume } Dv = \frac{2 \times 2 \times 50}{40} = 5m^3$$

(ii) Dimension of digester

$$\text{Volume of the digester } Dv = \frac{\pi}{4} d^2h$$

$$\text{for a balanced design } \frac{h}{d} = 2.5 \text{ (approx)}$$

$$\text{Substituting } \frac{h}{d} = 2.5 \text{ and } Dv = 5$$

$$Dv = 2.5 \frac{\pi d^3}{4} = 5$$

$$\textit{or } d = \sqrt[3]{\frac{5 \times 4}{2.5\pi}} = 1.36m = 1.35m \text{ (say)}$$

$$h = \frac{Dv}{\frac{\pi}{4} d^2} = 3.49m = 3.5m \text{ (say)}$$

Influence of Retention Time on Digester Size

$$\text{From } Dv = \frac{2VT}{40},\ Dv \propto T$$

if T is decreased then Dv is decreased.

Thus if $T = 40$ days, $V = 2m^3$

$$\text{Then } Dv = \frac{2 \times 2}{40} = 4m^3$$

Keeping d = 1.35 m

$$Dv = \frac{\pi}{4} d^2h$$

$$\text{or } h = \frac{4 \times 4}{\pi (1.35)^2} m = 2.79m = 2.8m \text{ (say)}$$

Thus reducing the retention time reduces the depth of excavation from 3.5m to 2.8m subsequently reducing the cost of the plant.

However, decreasing the retention time has the following disadvantages:

(i) More raw material will be needed to charge the digester.

(ii) The effluent will give bad odours and attract flies if retention time is decreased too much.

Gas holder

Generally the capacity of the gas holder is kept at 50% to 60% of daily gas production. Assuming 60% storage capacity.

$$\text{Volume of the gas holder} = \frac{2 \times 60}{100} = 1.2m^3$$

Keeping 5 cm clearance between gas holder and digester wall for easy up and down movement of gas holder

diameter of gas holder = (1.35—0.1)m = 1.25m

$$\text{Then height of gas holder } h = \frac{4V}{\pi d^2} = 0.97m$$

= 1m (say)

Thus the dimensions of the gas holder are:

d = 1.25m

h = 1m

Gas Pressure

Satisfactory delivery pressure of the gas is at 10 cm water column. The weight of the gas holder to exert 10 cm water column pressure is found out to be 125 kg for the above dimensions.

Construction of The Plant

The KVIC continuous integrated vertical plant consists of a digester and a gas holder which floats up and down the digester through a central guide (Drawing No. 1).

The digester is a circular dug out pit having a 10 to 15 cm thick concrete bottom at the centre of which is fixed a central guide pipe. The pit is lined with hollow concrete blocks (8″) and plastered to make a water seal tank. The digester top is at least 20 cm higher than ground level so as to prevent it from being flooded.

A mixing basin, of volumetric capacity of one day charge, feeds the digester through a 10 cm diameter inlet pipe.

The digested slurry leaves through an outlet pipe of same diameter. The opening of the inlet pipe is kept at about 25 cm above the top of the digester and that of the outlet pipe at about 8 cm below the top of the digester. This arrangement ensures automatic discharge of the digested slurry when the digester is fed with fresh slurry.

The gas holder consists of an angle iron structure cladded with mild steel sheet. A central pipe of slightly bigger diameter than the one of the digester guides the up and down motion of the gas holder. The gas holder when empty rests on a ledge made in the digester (Drawing No. 1).

Conclusion

Biogas technology is a simple technology that could have advantageously been propagated and popularised in Mauritius, were it not for the following constraints:

(i) High initial investment

(ii) Marginal return

(iii) Lack of raw materials.

The plant, through simple in construction, is costly and not within the reach of the average Mauritian farmer. A $2m^3$ biogas per day KVIC plant costs about Rs 10,000. So far only a few Mauritian farmers who could afford the price have taken to the novel technology. Some of them were under sanitary regulation constraints and did primarily set up the plants as pollution control devices. These farmers are now fervent adepts of biogas technology and enthusiastically impart its fine points to enquirers. In Mauritius where all houses, even those in villages, lie contiguous to each other the value of biogas plants as pollution control devices is inestimable. It is a real asset to the small poultry and pig keepers who have taken to farming in town or its vicinity.

Analysis of the cost benefit ratio of the KVIC plants shows a marginal return to wood and kerosene users. The demand on wood, the poorman's fuel in Mauritius, is resulting in rapid depletion of the already restricted local forest, thus aggravating the soil erosion problems.

It has further been observed that the number of animals kept by the small farmer is most of the time not sufficient to meet the plant requirements in raw materials.

Thus, any progress in the popularising of biogas technology lies on a plant prototype which could suit economic and other conditions of the small farmers, who are the main animal keepers in Mauritius.

An overall review of the work in the field reveals that the policy of popularising biogas technology should be reviewed and redirected on the following guidelines:

(a) Development of a less costly prototype compatible with raw materials availability.

(b) Identification of farmers with biogas production potential and providing incentives to the farmers to take to the new technology.

(c) Exchange of informations between the farmers and the promoting body.

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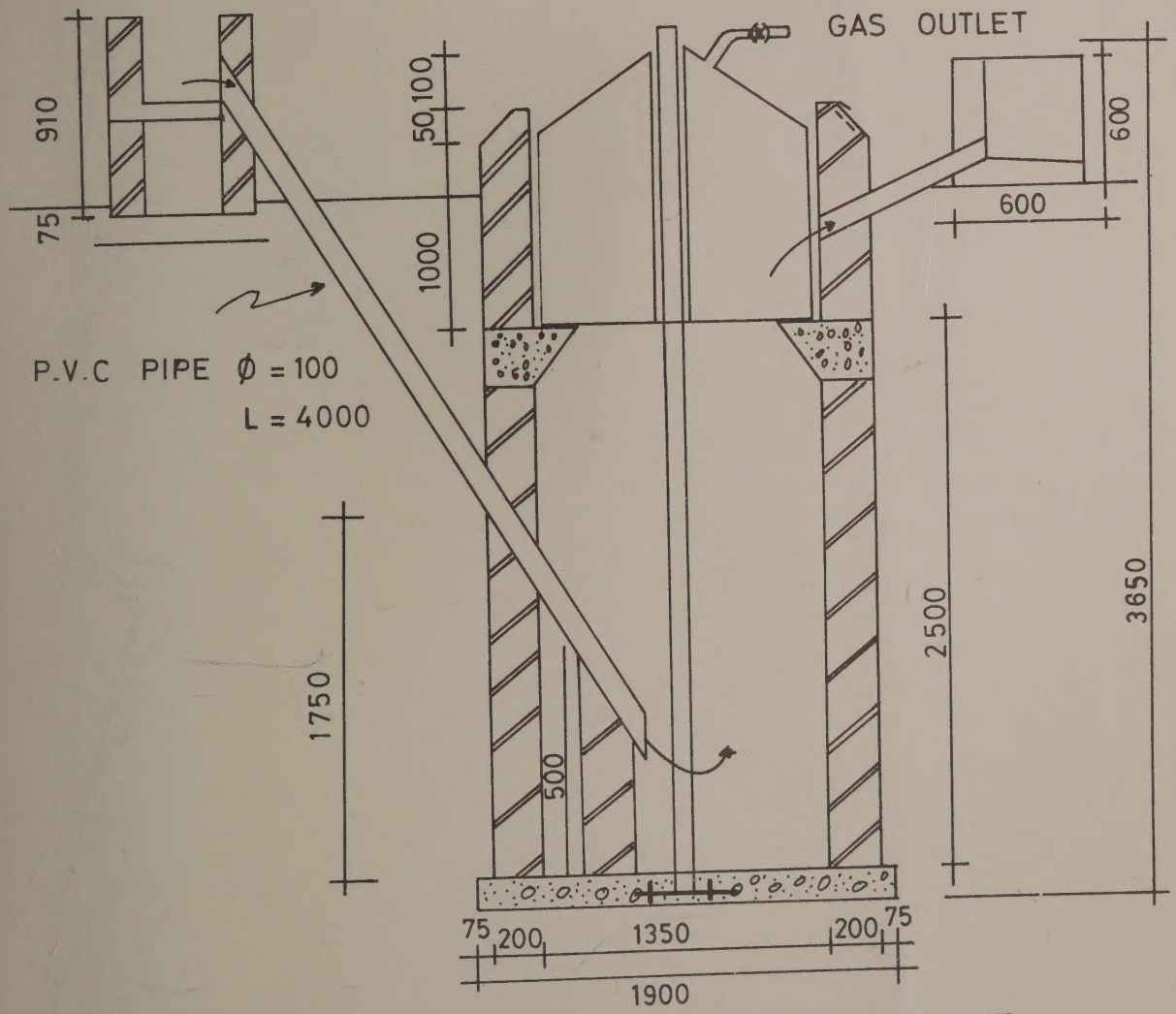
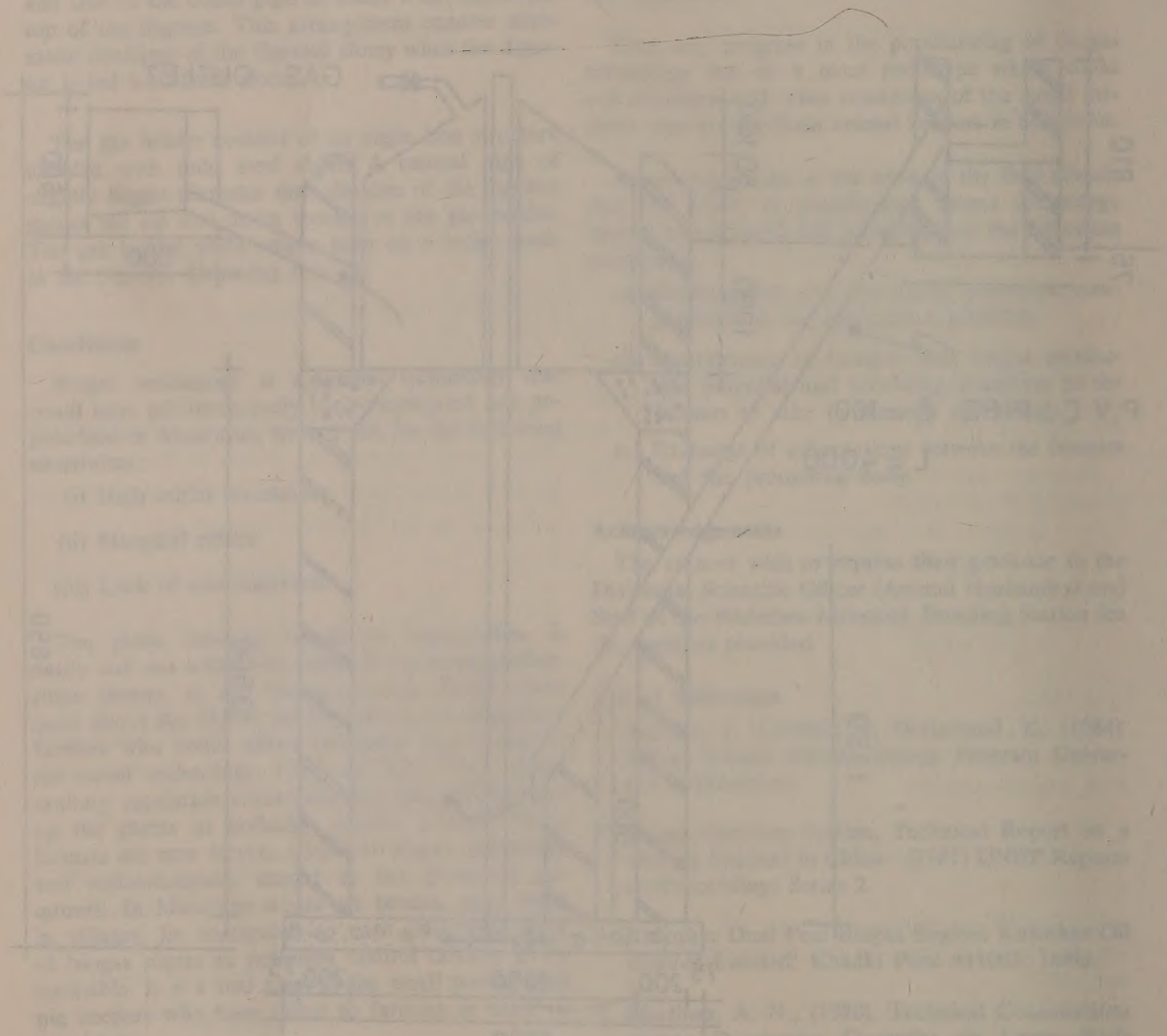


A 2 m^3 BIOGAS PER DAY VERTICAL PLANT

KVIC MODEL

All dimensions are in mm



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